TOPOGRAPHY OF THE LUNAR SOUTH POLAR REGION: IMPLICATIONS FOR THE LOCATION AND DISTRIBUTION OF PERMANENTLY SHADED AREAS;

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The recent possible discovery of ice at the lunar south pole from the Clementine bistatic radar experiment [1] requires permanently shadowed areas [2, 3, 4] that have been identified on the basis of the Clementine South Pole image mosaic [5, 6]. A -4 to -7 km elevation (compared to the mean lunar radius) in the south polar region, due to the South Pole-Aitken Basin, has been suggested as the cause of zones of permanent darkness [1]. In this study we perform an analysis of Clementine altimetry to understand the extent to which the location and distribution of any permanently shadowed region(s) can be clarified and quantified on the basis of our present knowledge of lunar topography. We recognize that the altimetry does not extend into the region in question but does completely surround it. Our analysis yields a conservative estimate of the elevation of the Moon in the vicinity of the south pole of -1 ± 2 km (relative to the mean) with an average long wavelength slope of <0.5°, much less than the 1.6° lunar obliquity. The data demonstrate that permanent shadowing is very unlikely to be a consequence of the South Pole-Aitken Basin and that any perennially dark regions must be a due to much shorter length scale (50 km) topography such as small craters, nearly centered on the pole.

Our analysis utilizes the best current topographic dataset for the Moon -- 72,548 radii measurements obtained from the Clementine LIDAR [7]. These radii, which have an absolute vertical accuracy of ~100 m with respect to the Moon's center of mass [8], were derived from laser ranges along the spacecraft ground tracks. The LIDAR collected successful range measurements in the lunar southern hemisphere down to latitudes of 79°S [7]. There are 752 radius measurements south of 70°S. In this region the along-track resolution, in tracks where there are data, is approximately 20 km; at 75°S the along-track resolution decreases to 60 km. The across-track resolution is governed by the spacing of orbital tracks and is approximately ~10 km at these high latitudes. There is an ~20° ($3x10^5$ km^2) data gap centered approximately on the south pole, shown in Fig. 1, which is greater than the size of the area of permanent shadowing [1]. However, while there are no direct measurements of lunar topography at the pole, it is possible to gain some understanding of the topographic character of this region from long wavelength aspects of the topography, the near-polar short wavelength topography, and the global topographic power spectrum.

Fig. 2 plots meridional planes of surface elevation through the south pole and illustrates that the massive South Pole-Aitken Basin dominates broad-scale southern hemisphere topography, even in the vicinity of the pole. Interpolation of the profiles over the polar gap yields an estimate of the south polar elevation of -1 ± 2 km, with a corresponding average slope of <0.5°. The large error in the estimate is a consequence of the interpolation necessitated by the data gap, but even with the uncertainly, the elevation of the pole appears to be significantly higher than reported by [1].

Regions near the south pole that are in permanent darkness must be surrounded on all sides by topography that blocks sunlight. The lunar obliquity of 1.6° enables the sun to reach an elevation of 1.6° at the pole from all directions, and for the pole to be in darkness the regional slopes must exceed this value plus the apparent radius of the Sun (~0.25°). Fig. 2 shows that the regional slope due to South Pole-Aitken is considerably smaller. The basin rim will have higher regional slope and Nozette et al. [1] contend that this structure is on the lunar nearside (outside the polar cone of exclusion). But even if it falls closer to the pole it does not fully encircle the area and very unlikely to produce permanent shadowing. Shoemaker et al. [5] identified an ancient, largely obliterated ~300-km diameter basin near the pole and proposed that it, combined with the rim of South Pole-Aitken, could explain much of the permanent shadowing. However, the irregular geometry and basin size and preservation state *(i.e.* associated shallow depth) lead us to favor an alternative explanation.

We note that the much shorter wavelength (~30 km-scale) topographic variance, based on

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the spatial distribution of the data near the pole and on the global lunar topographic power spectrum [7], is nearly 4 km. Such topographic power is dominated by impact structures and is adequate both in terms of amplitude and geometry (*i.e.* axisymmetry) if occurring within ~2° (~60 km) of the pole. The area that showed enhanced backscatter in the Clementine bistatic radar experiment was at least 6361 km^2 [1], which, if centered on the pole, would require encircling topography of order 2 km, or greater for a larger surface area. On the basis of current data it appears that placement within the confines of the South Pole-Aitken Basin and/or the 300-km ancient south polar basin is an insufficient condition for permanent shadowing. It is more likely that zones of permanent darkness in the lunar south polar region occur within small craters (order 30 km or less) nearly centered on the pole. Such structures should be targeted as areas of particular focus and study for future lunar exploration.

References. [1] Nozette S. et al. (1996) *Science, 274*, 1495. [2] Watson K. et al. (1961) *JGR, 66*, 3033. [3] Arnold J.R. (1979) *JGR, 84*, 5659.   [4] Ingersoll A.P. et al. (1992) *Icarus, 100*, 40. [5] Shoemaker E.M. et al. (1994) *Science, 266*, 1851. [6] Spudis P.D. et al. (1995) *LPSC, XXVI*, 1339. [7] Smith, D.E. et al. (1997) *JGR,* in press. [8] Zuber M.T. et al. (1994) *Science, 266*, 1839.
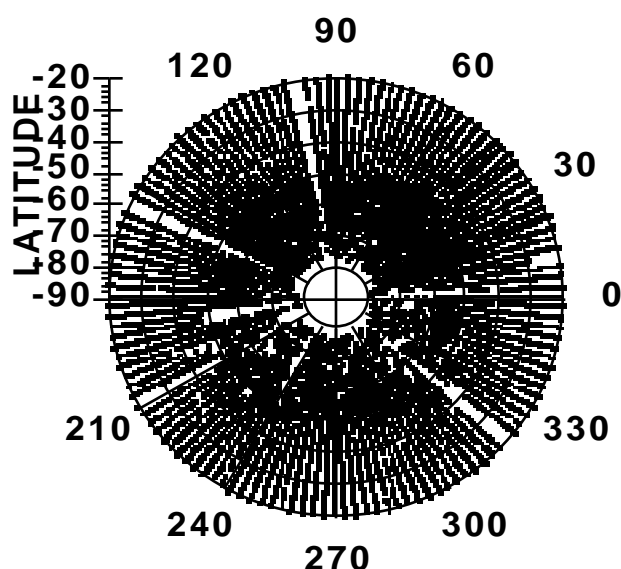

Figure 1. Distribution of surface elevations from Clementine altimetry between latitude 20°S and the south pole.
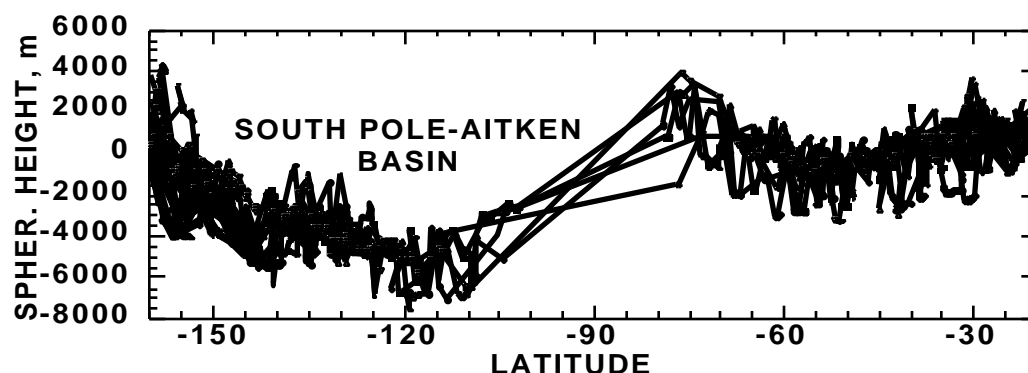

Figure 2. Meridional planes through the lunar south pole and the South Pole-Aitken Basin, with interpolation through the polar gap in altimetric coverage.